

## INTAKE CROSS-SHEETS FOR GAS CHROMATOGRAPHIC OVEN

1      **Technical Field**

2            The technical field relates to a gas chromatographic oven, and, in particular, to  
3            oven cooling efficiency.

4      **Background**

5            Gas chromatography (GC) is a physical method for the separation, identification,  
6            and quantification of chemical compounds. A sample mixture is injected into a flowing  
7            neutral carrier stream and the combination flows through a tube or chromatographic  
8            column. The inner surface of the column is coated or packed with a stationary phase. As  
9            the sample mixture and carrier stream flow through the column, the components within  
10          the mixture are retained by the stationary phase to varying degrees depending on the  
11          relative volatility of the individual components and on their respective affinities for the  
12          stationary phase. Different chemical compounds are retained for different times by the  
13          stationary phase. When the individual mixture components are released into the carrier  
14          stream by the stationary phase, the components are swept towards the column outlet to be  
15          detected and measured by a detector. The specific compounds in the components of the  
16          mixture can be identified and their relative concentrations determined by measuring peak  
17          retention times and peak areas, respectively.

18           A current trend in chromatography is towards improving sample cycle time to  
19          increase customer throughput. Cycle time includes sample injection time, oven heating  
20          time, sample separation time, and oven cooling or equilibration time. To decrease sample  
21          residence time, ovens are increasingly becoming more powerful (higher wattage coils)  
22          and smaller (lower thermal mass). As the size of the oven shrinks, often the ductwork for  
23          the oven's intake and exhaust becomes more complex in order to fit in smaller places or  
24          to be located more remotely from the oven.

25           A geometry that is utilized in small and fast GC ovens includes one or more axial  
26          boxer intake fans connected to an intake duct of convergent geometry. The intake fans  
27          supply fresh air to the GC oven through the converging intake duct. The use of a  
28          converging intake duct allows larger intake fans located remotely from a small oven to be  
29          used during cool-down. However, further improvements can be made to this system to  
30          cool the oven more quickly.

1   **Summary**

2       An oven intake for a gas chromatographic (GC) oven includes an intake duct  
3   having a convergent geometry to accommodate a small oven. The intake duct has one or  
4   more intake fans that supply airflow to the GC oven. The airflow originates from the one  
5   or more intake fans and flows through the intake duct into the GC oven. The oven intake  
6   further includes one or more cross-sheets positioned inside the intake duct parallel to a  
7   direction of the airflow flowing into the GC oven. The one or more cross-sheets reduce  
8   spin of the airflow originating from the one or more intake fans and guide the airflow  
9   through the intake duct into the GC oven.

10      A system for providing intake cross-sheets for a GC oven includes an intake duct  
11   having a convergent section to accommodate the GC oven located at one end of the intake  
12   duct. The system further includes one or more intake fans located remotely from the GC  
13   oven at an opposite end of the intake duct. The one or more intake fans supply airflow to  
14   the GC oven. The system further includes one or more cross-sheets positioned inside the  
15   intake duct parallel to a direction of the airflow flowing into the GC oven. The one or  
16   more cross-sheets reduce spin of the airflow originating from the one or more intake fans  
17   and reduce frictional losses of the airflow flowing into the GC oven.

18      A method for cooling an oven includes providing one or more cross-sheets inside  
19   an intake duct parallel to a direction of airflow flowing into the oven. The intake duct has  
20   a convergent geometry to accommodate the oven and has one or more intake fans located  
21   remotely from the oven. The one or more intake fans supply airflow for the oven. The  
22   utilization of the one or more cross-sheets reduces spin of the airflow originating from the  
23   one or more intake fans and reduces a cool-down time of the oven.

24   **Description of the Drawings**

25      The preferred embodiments of a system and method for providing intake cross-  
26   sheets for a gas chromatographic (GC) oven will be described in detail with reference to  
27   the following figures, in which like numerals refer to like elements, and wherein:

28      Figure 1 illustrates an exemplary oven intake with a converging intake duct and an  
29   intake fan;

30      Figure 2 illustrates a cutaway side view of the exemplary oven intake of Figure 1  
31   without cross-sheets showing the potential tendency for airflow spin;

32      Figure 3A illustrates a front view of the exemplary oven intake of Figure 1 with  
33   the intake fan;

1       Figure 3B illustrates another front view of the exemplary oven intake of Figure 1  
2 without the intake fan;

3       Figure 4 illustrates a cutaway top view of the exemplary oven intake of Figure 1  
4 showing the location of cross-sheets inside the intake duct;

5       Figure 5 illustrates an exemplary cross-sheet used in the exemplary oven intake of  
6 Figure 1 to improve airflow speed; and

7       Figure 6 illustrates a cutaway side view of the exemplary oven intake of Figure 1  
8 showing the direction of airflow into a GC oven.

9       **Detailed Description**

10      Current small and fast gas chromatographic (GC) ovens may use a converging  
11 intake duct to connect remotely located larger intake fans to a small oven. However, a  
12 converging geometry downstream of an axial flow fan generally sustains airflow spin  
13 induced by the axial flow fan that can lead to significant frictional losses. This effect, in  
14 the specific case of conical geometry, is discussed in Bleier, Frank, Fan Handbook:  
15 Selection, Application, and Design, McGraw-Hill, 1998 (pp 1.09-1.11), but may be  
16 extended to include all geometry of convergent shape. The induced friction greatly  
17 reduces the speed of the airflow and the volume of fresh air flowing into the oven from  
18 the intake fans.

19      An apparatus, system and method reduce the cool down time of GC ovens by  
20 supplying larger volumes of air through oven intake ducts. The system and method  
21 provide intake cross-sheets in an oven intake duct to disrupt and reduce airflow spin,  
22 increasing the flow rate of fresh air into the GC oven and reducing the overall cool-down  
23 time of the GC oven. In addition, because the improved airflow allows the oven wall  
24 temperature to quickly match the oven air temperature, the noise in the temperature signal  
25 may be reduced. As a result, the GC oven can reach an equilibrium “ready” state faster.  
26 Furthermore, the utilization of the cross-sheets may allow for flexibility in the design of a  
27 fast GC oven – specifically in the location and shape of the intake duct – without loss of  
28 performance. This flexibility may become increasingly significant as GC ovens continue  
29 on the trend of becoming smaller and faster.

30      Figure 1 illustrates an exemplary oven intake 100 with a converging intake duct  
31 120 and an intake fan 140 located upstream at one end of the converging intake duct 120.  
32 The intake fan 140 may be an axial boxer fan. The intake fan 140 supplies fresh air to a  
33 GC oven (not shown) located remotely from the intake fan 140 at an opposite end of the  
34 converging intake duct 120. As shown in Figure 1, the section of the intake duct 120 that

1 is connected to the intake fan 140 has an approximately square cross-section 190. The  
2 intake duct 120 then converges to a rectangular cross-section 195 extending to the GC  
3 oven. As an example, an intake duct on an Agilent 6850GC oven is a duct of  
4 approximately 92 mm square cross-section (to accommodate a 92 mm boxer fan), that  
5 converges to a rectangle of 35 mm x 92 mm cross-section (to fit behind the keyboard and  
6 display of a GC). The intake duct 120 may or may not have a conical shape.

7 Figure 2 illustrates a cutaway side view of the exemplary oven intake 100 without  
8 cross-sheets showing the potential tendency for airflow spin 210. The intake duct 120 is  
9 shown with a convergent geometry 165. The intake fan 140 supplies airflow in the  
10 direction 180. The airflow flows through the converging intake duct 120 and into the GC  
11 oven in the direction 185. An intake flap 250 directs the airflow direction 185. Because  
12 the intake duct 120 has a non-uniform converging cross-section, the spin 210 induced by  
13 the axial intake fan 140 about an axis 170 may be sustained through the length of the  
14 intake duct 120. Airflow spin 210 may originate from a source other than the intake fan  
15 140. The spin 210 may increase the effective distance the airflow travels, which in turn  
16 increases the frictional losses the airflow experiences due to interaction with the intake  
17 duct wall. This increased friction decreases the airflow flowing into the GC oven. To  
18 increase the velocity and volume of the airflow flowing into the GC oven, one or more  
19 cross-sheets 110 (shown in Figure 3B) may be added to the intake duct 120 to reduce the  
20 airflow spin 210.

21 Figure 3A illustrates a front view of the exemplary oven intake 100 with the  
22 intake fan 140. Figure 3B illustrates another front view of the exemplary oven intake 100  
23 without the intake fan 140. Two cross-sheets 110 are shown in Figure 3B. The cross-  
24 sheets 110 are located inside the intake duct 120 near the intake fan 140, such as 2 cm  
25 from the fan 140, and parallel to the direction of the airflow. The cross-sheets 110 shown  
26 here are trapezoidal in shape, with bases slightly undersized from 35 mm and 92 mm, to  
27 approximate the convergent section of the oven intake 100. However, other shapes and  
28 sizes of cross-sheets may be employed. The cross-sheets 110 may be secured to the  
29 intake duct wall by riveting metal tabs 115. If only one cross-sheet is used, the cross-  
30 sheet may be placed off-centered, for example, at one-third of the width of the intake duct  
31 120 or one-third the diameter of the intake fan 140, to disrupt the spin 210. Additional  
32 cross-sheets may be used. For example, additional cross-sheets may be added alongside  
33 the cross-sheets 110 shown. One, two, three or more may be added. Also, cross-sheets  
34 may be added orthogonal to or at right angles to the cross-sheets 110 shown. A preferred

1 embodiment is two cross-sheets placed in an “=” configuration at one-third and two-thirds  
2 of the width of the intake duct 120 or intake fan 140 diameter. Other arrangements of  
3 cross-sheets are possible with the same beneficial effect.

4 Figure 4 illustrates a cutaway top view of the exemplary oven intake 100 showing  
5 the location of the cross-sheets 110 inside the intake duct 120. The intake fan 140  
6 supplies airflow in the direction 180. The airflow flows through the converging intake  
7 duct 120 into the GC oven. As noted above, the intake fan 140 may induce airflow spin  
8 210 about an axis 170. The utilization of the cross-sheets 110 disrupts 220 the tendency  
9 for the airflow to maintain spin 210 so that the airflow is guided 230 through the intake  
10 duct 120 to reach the GC oven. As a result, the frictional losses may be reduced because  
11 the distance over which any piece of fluid interacts with the intake duct wall is reduced.  
12 The reduced frictional losses may lead to increased airflow speed and consequently more  
13 fresh air flowing into the GC oven during cool-down. The cross-sheets 110 preferably  
14 are located close to the intake fan 140 to guide the airflow as soon as possible, such as 2  
15 cm from the intake fan 140.

16 Figure 5 illustrates an exemplary cross-sheet 110 used in the exemplary oven  
17 intake 100 to improve airflow speed. The metal tabs 115 are riveted to secure the cross-  
18 sheets 110 to the intake duct wall. Other methods of securing, for example, screws, bolts,  
19 etc., may be used. The cross-sheets 110 shown in Figure 5 has a converging shape 160  
20 that conforms to and approximates the intake duct’s convergent geometry 165.

21 Figure 6 illustrates a cutaway side view of the exemplary oven intake 100  
22 showing the direction 185 of airflow into the GC oven. As stated above, the intake fan  
23 140 supplies airflow in the direction 180. The airflow is guided 230 by the cross-sheets  
24 110 located inside the intake duct 120 directly in front of the intake fan 140. The guided  
25 airflow flows through the converging intake duct 120 into the GC oven in the direction  
26 185. The utilization of the cross-sheets 110 reduces the airflow spin 210 induced by the  
27 intake fan 140 and sustained by the convergent geometry 165 of the intake duct 120,  
28 increasing the flow rate and volume of fresh air into the GC oven.

29 The overall cool-down time of the GC oven may be reduced as the flow rate of  
30 fresh air into the GC oven is increased. Also, the noise in the temperature signal may be  
31 reduced because the improved airflow allows the oven wall temperature to quickly match  
32 the oven air temperature. As a result, the GC oven can reach an equilibrium “ready” state  
33 faster. In addition, the utilization of the cross-sheets 110 may allow for flexibility in the  
34 design of a fast GC oven without loss of performance. For example, converging intake

1 ducts may be used to allow larger intake fans located remotely from a small oven to be  
2 used during cool-down without suffering frictional losses induced by the airflow spin  
3 210.

4 The following experiments illustrate the benefit of using the cross-sheet 110,  
5 specifically measured as the flow rate of air exhausted from the GC oven into open air.

6 One type of experiment is a battery of airflow measurements. In this experiment,  
7 an oven without insulation or support, such as an Agilent 6850 inner oven, is equipped  
8 with an axial fan 140 and one or more cross-sheets 110. The cross-sheets are placed in  
9 various locations in the oven intake duct 120. The oven stirring fan is not present in this  
10 experiment. The oven is sealed with a plastic cover.

11 The flow rate of air exhausted from the oven is measured using both a vane  
12 anemometer and a hot-wire anemometer. An anemometer is an instrument for measuring  
13 and indicating airspeed. Because the airspeed varies over the cross-section of the oven's  
14 exhaust duct (not shown), four points are taken to generate an average velocity. The  
15 experiment is performed at room temperature and under standard pressure. Table 1  
16 illustrates the results of this experiment.

17 **Table 1**

Number of Cross-Sheets	Airspeed (m/s)	Airspeed (m/s)
	Vane Anemometer	Hot-wire Anemometer
0	3.300	3.1725
1	3.475	N/A
2	3.650	3.450
3	3.675	3.425

18

19 Although some discrepancy exists over absolute values between the vane  
20 anemometer and the hot-wire anemometer, the trend is evident. The airspeed increases  
21 with the presence of the cross-sheets 110. For this particular application little if any  
22 improvement is shown when using more than two cross-sheets 110. As a result, the  
23 preferred number of cross-sheets is two.

24 For the special case of one cross-sheet, the cross-sheet is off-centered, for  
25 example, at one-third of the width of the intake duct, to generate the beneficial result  
26 illustrated in Table 1. If the cross-sheet is centered along the width of the intake duct, the  
27 cooling time actually increases.

A second type of experiment is more application specific. This experiment compares the cooling profile of GC ovens, such as Agilent 6850GC prototype ovens, that are equipped with one or more cross-sheets 110 with the same GC ovens without the cross-sheets 110. Table 2 illustrates the cool-down time of an Agilent prototype oven, which is geometrically similar to a standard Agilent 6850GC oven with the exception of the wall material. In addition, a more efficient intake fan 140 is used in this experiment, and the observed benefit of two cross-sheets 110 is apparent as shown below in Table 2.

**Table 2**  
Prototype Oven with More Efficient Fan

Cross-sheets?	Cool-down Time (min)
No	4.07
Yes	3.40

As shown in this experiment, the addition of two cross-sheets 110 inside the intake duct 120 reduces the cool-down time of the GC oven by more than 16%.

13           While the system and method for providing intake cross-sheets for a GC oven  
14 have been described in connection with an exemplary embodiment, those skilled in the art  
15 will understand that many modifications in light of these teachings are possible, and this  
16 application is intended to cover variations thereof.